COMPLETION REPORT

GREENWOOD (U-4749) AND WARWICK (U-4878) PROJECTS

PASSAIC COUNTY, NEW JERSEY AND ORANGE COUNTY, NEW YORK

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ABSTRACT

The Greenwood and Warwick Projects were generated in 1977 to appraise the potential for high-grade uranium vein deposits in the Reading Prong of New York, New Jersey, and Pennsylvania. Evaluation of these projects, however, was never completed because local governments passed bans on uranium exploration. As a result, these projects were cancelled in late 1980.

The Reading Prong is an exposure of metasedimentary and metavolcanic rocks which were metamorphosed to upper amphibolite and lower granulite facies during the Grenville Orogeny at 1100 m.y. During this orogeny the metamorphic rocks were intruded by significant quantities of granitic rock, subjected to multiple sets of folding, and faulted. Intrusion and alteration of these rocks continued beyond the peak of Grenville prograde metamorphism to 950 m.y. The Reading Prong is best known for hosting the zinc deposits at Franklin, New Jersey. In addition, it hosts numerous magnetite deposits which were mined from the mid 1700's through the early 1900's. Uranium mineralization has been identified at many sites throughout the Prong. Most commonly it is associated with the magnetite concentrations, but it is also hosted in granitic intrusives and marbles.

At Greenwood and Warwick, uranium is found in stratabound settings within metasedimentary gneisses, in zones of fracture-controlled hydrothermal mineralization, and in a granite dike. Exxon's evaluation of these projects included geologic mapping, rock chip geochemistry and petrography, soil chemistry, ground geophysics, aeroradiometrics, and core drilling. Of eleven core holes drilled on the two contiguous projects, two were ore holes, three were strongly mineralized, five were weakly mineralized, and one was anomalous. This drilling negatively evaluated one target zone, but four other target areas must be drilled to complete an evaluation of these projects.

In addition to the project work, most of the uranium shows in the Reading Prong were visited and appraised in a reconnaissance manner. Several of these shows have significant potential for hosting a uranium vein deposit.

A syngenetic-metamorphic model of metallogenesis is proposed for the Reading Prong. This model involves the syngenetic deposition of metals in a sedimentary/volcanic environment, recrystallization and possible concentration during Grenville prograde metamorphism, and upgrading during late Grenville alteration and intrusion. This model can be applied in the exploration of other high-grade metamorphic terranes, particularly the Grenville rocks of the Appalachian system.

The termination of these projects because of political problems demonstrates the necessity of incorporating a public affairs strategy into uranium exploration programs. The exploration industry must be prepared to respond quickly and comprehensively to the public's concern over nuclear issues. A particularly important aspect of this strategy is planning for the rapid execution of the geologic evaluation and drilling of projects in sensitive areas. This will provide management with the geologic merits of defending a property should a public debate arise.

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INTRODUCTION

The Frontier Uranium Group conducted a reconnaissance of crystalline rock terranes in the eastern United States during 1975 and 1976. These efforts identified the Reading Prong of New York, New Jersey, and Pennsylvania as the most promising uranium province in the East. A submittal in late 1976 led to the generation of the Greenwood and Warwick Projects in the northwestern portion of the Reading Prong, along the New York - New Jersey state line. Surface evaluation and drilling of these projects was conducted from 1977 to 1980. Final evaluation drilling was scheduled for the fall of 1980, but work was terminated in July when these projects began receiving unfavorable press coverage. Pressure from anti-nuclear activists prompted the townships involved to pass bans on uranium exploration. As a result, the Greenwood and Warwick Projects were canceled in November 1980.

This report describes the results of the geologic investigations in this area, the evaluation of these projects, and a genetic model for the occurrence of uranium and other metals in the Reading Prong. The data and materials collected in the course of this work have been stored in a manner described in Appendix 1.

GENERAL GEOLOGY OF THE READING PRONG

The Reading Prong is the central exposure of three major belts of Precambrian crystalline rocks which are aligned in a nearly continuous fashion along the east coast of the United States. To the south, the Blue Ridge anticlinorium runs from Alabama to Pennsylvania, and to the north the Berkshire-Green Mountain anticlinorium extends through Massachusetts and Vermont. As shown in Figure 1, the Prong is bounded on the north and west by the Paleozoic sediments of the Appalachian Valley and Ridge Province. On the south and east, the Precambrian is in fault contact with Triassic basin sediments and volcanics throughout Pennsylvania and New Jersey. In New York, east of the Hudson River, it is in fault contact with early Paleozoic metamorphic rocks of the New York City Group.

The metamorphic rocks of the Prong include quartzo-feldspathic gneisses, amphibolites, calc-silicate rocks, and marbles. They have been regionally metamorphosed to upper amphibolite and lower granulite facies. Abundant intrusives were emplaced in these rocks in a generally concordant fashion during the regional metamorphism; these range in composition from alaskites and hornblende granite to syenites and monzonites (Young, 1978). Age dates by Tilton, et al. (1960), Long and Kulp (1962), and Dallmeyer (1972) have set this metamorphism and intrusive activity between 1050 and 1150 m.y., during the Grenville Orogeny. Paleozoic orogenies and regional uplift produced local retrograde alteration usually characterized by abundant epidote and chlorite (Dallmeyer, 1972, p. 179).

Folding has been complex and ranges in magnitude from a few inches to several miles. The major fold system is generally isoclinal, overturned to the northwest, and plunges to the northeast parallel to the regional trend. Dallmeyer (1972, p. 58) recognizes three distinct phases of folding in the northern Prong; all folds, however, are attributed to one period of plastic deformation during the Grenville Orogeny.

High angle, northeast trending, longitudinal faults break the Precambrian into a series of structural blocks which have different metamorphic and structural characteristics (Offield, 1967, p. 7, and Dallmeyer, 1972, p. 71). Numerous transverse faults with small displacements also occur. In most areas three sets of joints are developed: transverse (most abundant and best expressed), longitudinal (often poorly expressed), and oblique (least common). All fracturing is post folding. Dallmeyer (1972, p. 88) believes that movement in the north Prong may have initiated about 1000 m.y. ago and continued, being reactivated by several periods of uplift, until the present.

Work by Drake (1970) and others in the southwestern portion of the Prong show the Precambrian to be a series of thin, allochthomous slices overlying lower Paleozoic rock. These slices are interpreted to be part of a large nappe structure rooted east of the Prong that was emplaced during the Taconic Orogeny of late Ordovician time. In the northeast, however, Smith (1969), Dallmeyer (1972, p. 99-109 and 1974), and Young (1978) argue that the tectonic setting is autochthonous, the result of large scale basement uplift along the longitudinal faults. Dallmeyer (1972, p. 109) suggests that the transition between transported and rooted Precambrian occurs northwest of Morristown, New Jersey.

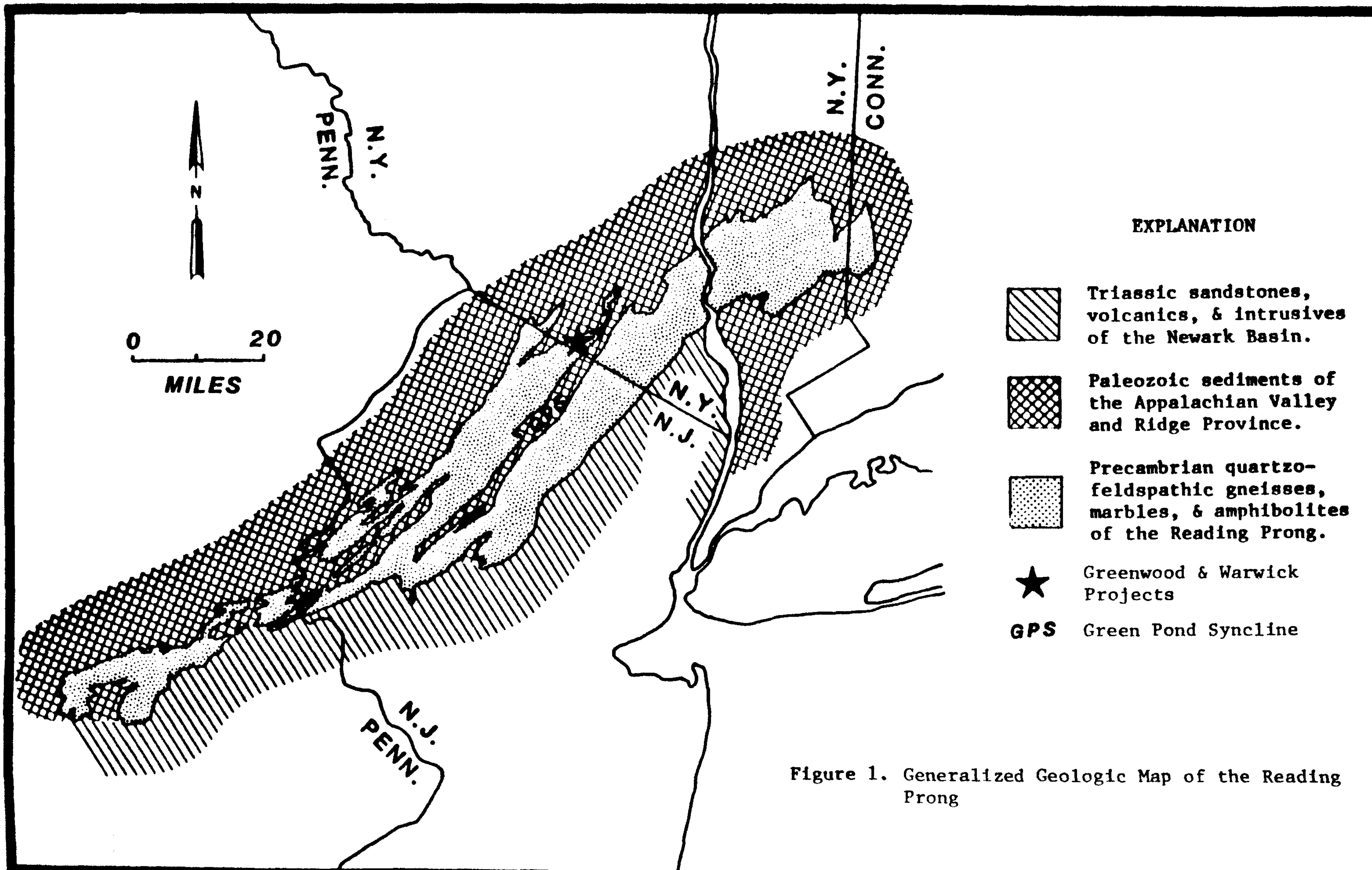

Figure 1. Generalized Geologic Map of the Reading Prong

Pleistocene glaciation denuded the Precambrian highlands as far south as Dover, New Jersey. The glaciated terrain of the northern Prong is characterized by rugged topography with abundant Precambrian outcrop and local thin veneers of till. Thicker deposits of glacial drift and post glacial alluvium cover low lands to depths locally in excess of 185 feet. The Wisconsin terminal moraine stretches east-west across the highlands at the latitude of Dover and marks an abrupt change in the morphologic expression of the highlands. To the south, the topography is much less rugged with sparse outcrop and thick soil cover.

The Magnetite Ore Bodies

Magnetite ore bodies occur throughout the Reading Prong in quartzo-feldspathic gneisses, amphibolites, skarns, and pegmatites. In the two major mining districts of the Prong, the Dover and the Sterling Lake - Ringwood districts of New Jersey and New York, production between the 18th century and the 1950's has been in excess of 30 million tons of iron ore (Sims, 1958, and Hotz, 1953). The ore bodies are concentrated in elongate zones that parallel rock units and foliation. Widths of the zones of ore bodies range from several tens of feet to as much as two miles and lengths from less than one-half mile to more than 20 miles. These zones contain layers rich in magnetite separated by layers of barren rock. High concentrations within the magnetite rich layers form ore bodies. Contacts are commonly abrupt gradations from disseminated magnetite in the host rock to enriched zones of magnetite in the ore bodies. These are generally conformable features which are tabular and pod or lath shaped. The ore bodies range in width from inches to 40 feet and in length from 10 feet to greater than two miles. They strike and dip parallel with host rock foliation and plunge parallel with lineation. Most ore bodies pinch and swell along their major axis, but they are generally not folded. Brittle deformation followed emplacement of the ore, and the magnetite bodies are commonly offset by transverse faults. Figure 2 is Hotz's diagrammatic sketch of a typical ore body (1953, p. 202).

Characteristics of ore mineralization vary with the host rock and, within the same host rock, among the mining districts. The major mines were located in gneisses and amphibolites as lath-shaped deposits of massive, medium to fine grained magnetite. The best examples of these deposits are in the Dover and the Sterling Lake districts where they are described as pinching and swelling, pencil-shaped bodies which commonly reach 1000 to 2000 feet in length (Sims, 1958, and Hotz, 1953). Smaller mines were worked in bodies of disseminated magnetite occurring in all Precambrian rock types.

Magnetite is the predominant ore mineral, but hematite is also reported in several deposits. It occurs both as a primary mineral intergrown with magnetite and as martite. Hematite forms up to 20 per cent of certain deposits (Hotz, 1953, p. 206; Sims, 1958, p. 59). Ilmenite and rutile are also found as intergrowths with magnetite. The paragenesis of these iron titanium oxides is the subject of a thorough discussion by Baker and Buddington (1970, p. 55-64). Sulfides are frequently found with the magnetite. They commonly include pyrite, pyrrhotite, and chalcopyrite and may constitute up to two or three percent of the ore. The most abundant gangue minerals are apatite and quartz; others

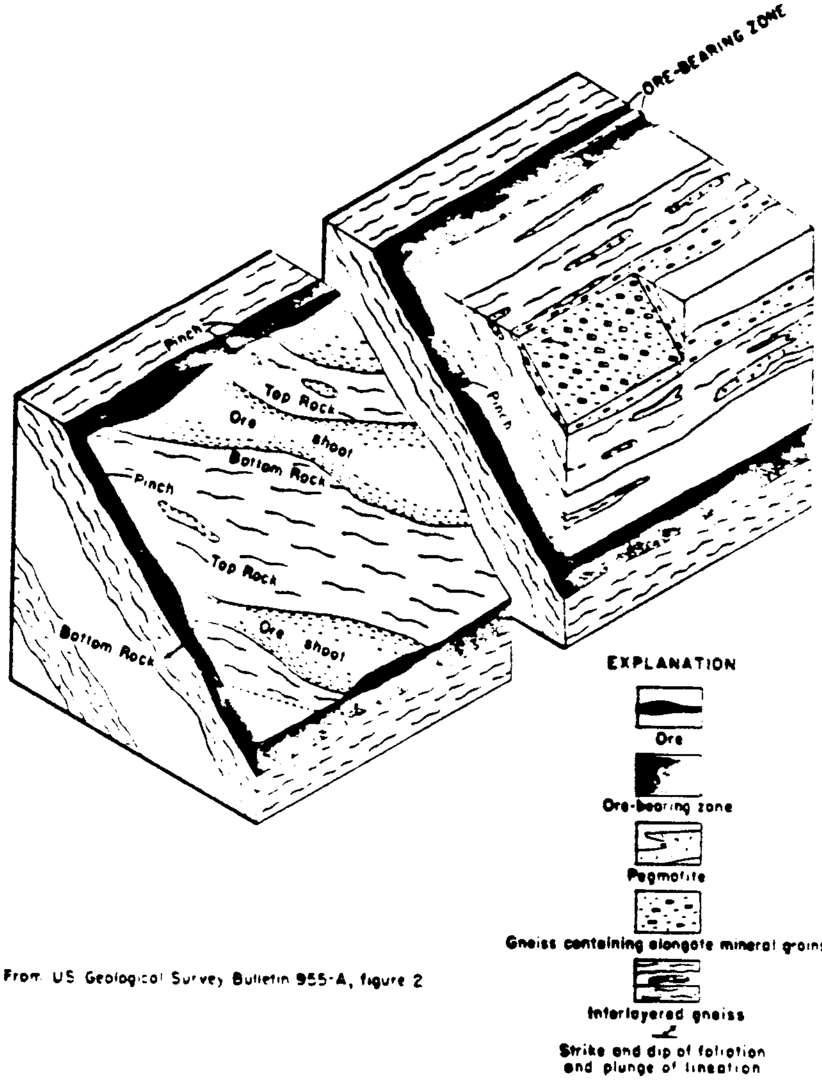

Figure 2. Idealized block diagram of a typical magnetite ore body (from Hotz, 1953, Figure 47).

include biotite, chlorite, actinolite, albite, epidote, calcite, sphene, rutile and tourmaline. Distribution of gangue minerals varies from disseminated to concentrated layers which parallel foliation.

The origin of these deposits is the subject of considerable discussion. Bayley (1910), Sims (1958), Buddington (1966), Collins (1969), Baker and Buddington (1970), and Kastelic (1979) provide good summaries of the arguments which have been presented. Proposed origins include: 1) metasomatic replacement of host rock by iron-rich fluids of predominantly magmatic origin (Baker and Buddington, 1970); 2) recrystallization of amphiboles during regional metamorphism releasing iron which formed magnetite in low pressure zones (Collins, 1969); and 3) metamorphism and reconcentration of syngenetic, sedimentary iron formations (Kitchell, 1857, p. 11-13; Grauch, 1978; Cooper, 1978; and Kastelic, 1979). This author supports the metamorphic-syngenetic model for reasons discussed under the metallogenesis section of this report.

The Zinc Deposits

The Reading Prong is best known for hosting the zinc deposits at Franklin and Sterling, New Jersey. The ore bodies are composed of bed-like or lens-like bodies of ore and calc-silicate minerals arranged in a laminated fashion in the hosting Franklin Marble. Predominant minerals of the ore zones include franklinite, willemite, zincite, calcite, and manganese-bearing silicates of the olivine and chondrodite groups. Most of the remaining minerals identified at Franklin, in excess of 230, are products of weathering or a low-temperature hydrothermal alteration event which followed the peak of Grenville metamorphism. In addition to the zinc mineralization, a magnetite horizon three to eight feet thick parallels the zinc ore bodies; the magnetite contains significant graphite and manganese but is free of zinc. All metal-bearing horizons are conformable to the sedimentary structures in the enclosing marbles. These deposits are currently believed to be stratiform deposits of sedimentary origin which have been recrystallized and deformed by the Grenville Orogeny (Frondel & Braum, 1974).

The Uranium Occurrences

Occurrences of uranium mineralization, rare-earth elements, and radioactive anomalies have been reported in numerous locations throughout the Reading Prong. Uranium mineralization has been documented in various published sources including: Bayley (1910, p. 116 & 152), Wells et al (1933), Walthier (1955), Engineering and Mining Journal (1957), Montgomery (1957), Klemic et al (1959), McCarley (1961), Offield (1967), Smith (197-), Grauch and Zarinsky (1976), and Grauch (1978). The following Atomic Energy Commission and Department of Energy publications also discuss these occurrences: A.E.C. reports RMO-96, RMO-108, RMO-111, RMO-112, and TEI-67 and D.O.E. reports GJBX-2(79), GJBX-90(80), GJBX-128(80), and GJQ-003(80). Rare-earth element occurrences have been discussed by Klemic et al (1959) and Williams (1967). The Bureau of Topography and Geology of the State of New Jersey, at Trenton, maintains an unpublished list of 68 reported occurrences of "Radioactive Minerals". Many of the occurrences on this list, however, are monazite placers. (Copies of this list are in our files).

The uranium shows of the Reading Prong can be grouped into three general, host-rock associations: 1) magnetite-bearing zones in the quartzo-feldspathic gneisses, 2) granitic intrusives, and 3) marble. At the Greenwood and Warwick Projects, our detail work shows that both magnetite and granite associated mineralization is present and that both types have been modified by fracture-controlled hydrothermal alteration. The above associations, nevertheless, are useful generalizations for categorizing the various uranium shows found throughout the Reading Prong.

The magnetite-associated uranium mineralization is the predominant type of show in New York and northern New Jersey. This association is also present in north-central New Jersey, most commonly west of the Green Pond Syncline (Figure 1). The uranium in these shows typically occurs as rounded crystals of uraninite 0.5 to 5 mm in diameter. The uraninite is hosted along grain boundaries or within crystals of clinopyroxene, hornblende, and, less commonly, magnetite and scapolite. At the Greenwood and Warwick Projects uraninite is also hosted in epidote and allanite. The uraninite mineralization is conformable to the compositional layering and/or foliation of the host rocks; thus it appears to be stratabound in nature. The host rocks are quartzo-feldspathic gneisses which contain horizons enriched in magnetite and often zones of marble or calc-silicate rocks. The uraninite often occurs within inches to several feet of high concentrations of magnetite. Good examples of this type mineralization are the Phillips Mine at Camp Smith, Westchester and Putnam Counties, New York; the Ringwood Mine, (land check number U-5636), Passaic County, New Jersey; the Andover Mine, Sussex County, New Jersey; and the Cranberry Lake Mine (land check number U-5635 and submittal U-5833), Sussex County, New Jersey. The uranium mineralization at the magnetite mines of the Greenwood and Warwick Projects is also an excellent example of this association.

The uranium shows associated with granitic intrusives are most common in the central portion of the New Jersey Reading Prong, west of the Green Pond Synclinorium. These shows are probably also produced by uraninite which occurs within or near the contact of a distinctive group of granitic intrusions. The intrusives are coarse-grained to pegmatitic, equigranular, and luecocratic. Microcline is the predominant feldspar, and it is often pinkish-red in color. These granites are probably S-type, produced by anatexis of rocks deeper in the orogenic pile. They rose to their level of emplacement late in the Grenville event. The best example of this type show occurs along the crest of Bowling Green Mountain in Passaic County, New Jersey (land check U-5653).

The marble associated shows occur in the Franklin Marble in the area around Easton, Pennsylvania. These consist of uraninite in hydrothermally altered marbles. They are probably the products of hydrothermal fluids associated with late-stage alteration and/or intrusion of the uraniferous granites.

In addition to these three general types of shows, uranium is also found in limited concentrations associated with rare-earth element mineralization. These occurrences are associated with magnetite-rich horizons and may be a subtype of the magnetite-associated show. They occur in north-central New Jersey, east of the Green Pond Syncline (Klemic et al, 1959, and Williams, 1967).

GEOLOGY OF THE GREENWOOD AND WARWICK PROJECTS

The Greenwood and Warwick Projects are located along the same geologic trend south and north, respectively, of the New York - New Jersey state line. The favorable sequence of rocks hosting this mineralization crops out along Warwick and Taylor Mountains for five miles from Upper Greenwood Lake, Passaic County, New Jersey, to the village of Bellvale, Warwick Township, Orange County, New York (Figure 3).

Offield (1967) mapped the terrane north of the New Jersey state line at a scale of 1:48,000. His work plus other mapping in this region by Baker and Buddington (1970), Helenek (1971), Dallmeyer (1972) and Kearns (1977) provide a regional geologic framework for the Greenwood and Warwick Projects. Our geologic map of these projects is presented as Figure 4. This map is the result of contributions by M. H. Bailey, J. R. Carden, R. Guzowski, and R. E. Williams. The rock types, alteration, structures, magnetite deposits, and uranium occurrences displayed on this map are discussed below.

Rock Types and Petrogenesis

Table 1 describes rock types present at Greenwood and Warwick. Offield's 1967 report provides modal data for these rocks and a more elaborate description of their distinguishing characteristics. Comments on the distribution of these rock types and other important features follow:

Chlorite Schist: No outcrop of this unit was found, but it was intercepted in drill holes G-3 and G-7. It is fault gouge along the major longitudinal fault which abuts the Precambrian gneisses against Devonian sandstones along the southeast flank of the Greenwood Project.

Diabase: A diabase dike crops out on the Greenwood Project at New York state plane coordinates N436,050 and E492,010; it is too small to be represented on Figure 4. Diabase has also been intercepted in drill hole G-5.

Granite: A luecocratic granite dike intruding marble was encountered in drill hole G-7. There appears to be no surface expression of this intrusive.

Pegmatites: ("Alaskite" in Offield, 1967): North of the state line the pegmatites tend to occur as elongate zones or layers; south of the state line they are podiformal in nature.

Graphite-Biotite Gneiss: ("Graphitic feldspar-quartz gneiss" in Offield, 1967): This unit flanks Warwick and Taylor Mountains on the east-southeast.

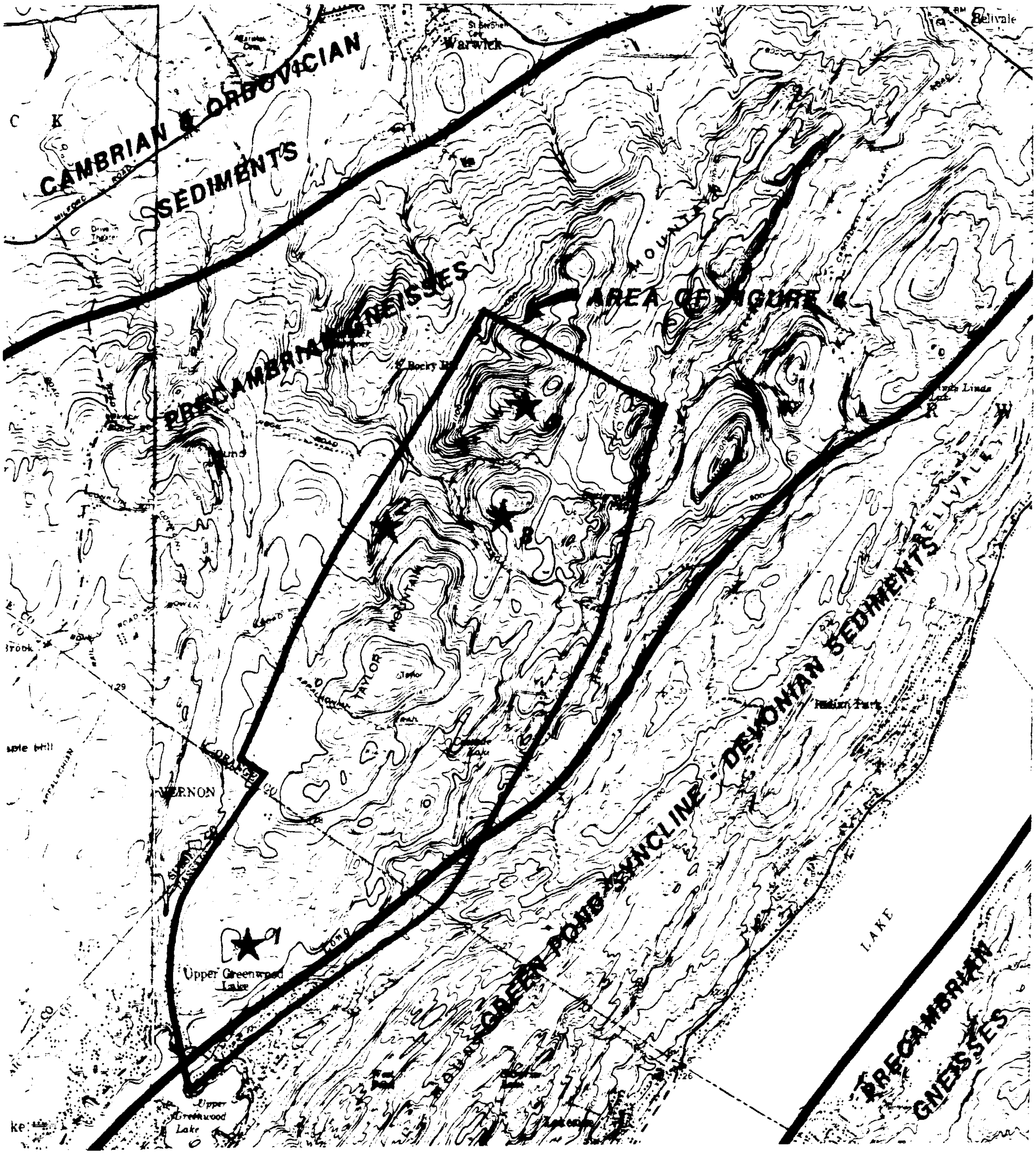

Figure 3. Generalized Geologic Map of the Warwick and Taylor Mountain Areas.

★ Magnetite Mines

1. Centennial
2. Raynor
3. Parrott
4. Standish

0 — 1 Mile

TABLE 1: CHARACTERISTICS AND PETROGENESIS OF ROCK TYPES PRESENT AT THE GREENWOOD AND WARWICK PROJECTS

Rocks in approximate age sequence, youngest to oldest

Rock Type	Texture	Foliation	Compositional Banding	Mineral Constituents (Listed from least to most abundant within each category) Major	Minor	Trace	Petrogenesis
Chlorite Schist	Schistose	Strong	None	Chlorite	-----	-----	Fault gouge; Precambrian to post-Devonian movement
Diabase	Ophitic	None	None	Pyroxene, plagioclase	Hornblende, biotite	-----	Late Precambrian, early Paleozoic intrusive
Granite	Allotriomorphic, equigranular	None	None	Plagioclase, quartz, microcline	-----	-----	Late Grenville, S-type granitic intrusive
Pegmatite	Massive, pegmatitic to seriate	Weak	None	Quartz, plagioclase, microcline	-----	Hornblende, magnetite biotite	Anatexis during Grenville prograde metamorphism and/or recrystallization of rhyolitic ash-fall horizons
Graphite-Biotite Gneiss	Gneissic to schistose, inequigranular	Moderate to strong	Weak to moderate	Biotite, microcline, plagioclase, quartz	Sillimanite, chlorite, graphite, garnet	Zircon, magnetite, apatite	
Biotite Gneiss	Gneissic to schistose, inequigranular	Strong	Weak to moderate	Biotite, quartz, microcline, plagioclase	Hornblende, chlorite	Zircon, magnetite, apatite, garnet	
Marble	Granoblastic, equigranular to inequigranular	Weak	Weak	Calcite	Diopside		
Pyroxene-rich Rock	Granoblastic, equigranular	Weak	Weak to strong	Microcline, plagioclase, diopside	Biotite, hornblende, chlorite, epidote, pyrite, chalopyrite, pyrrhotite, garnet	Allanite, apatite, sphene, pyrite, magnetite, calcite	Intercalated dirty sandstones, shales, impure dolomites, and volcanoctastics. Metamorphosed to upper amphibolite, lower granulite facies during Grenville orogeny. Subjected to late-Grenville alteration.
Microcline Gneiss	Granoblastic, equigranular to seriate	Weak to moderate	Weak	Quartz, microcline, plagioclase	Hornblende, chlorite, biotite, epidote, pyroxene	Allanite, zircon, apatite, sphene, magnetite	
Hornblende Gneiss	Granoblastic, equigranular	Moderate to strong	Weak to moderate	Quartz, hornblende, microcline, plagioclase	Magnetite, epidote, chlorite, pyroxene, biotite	Allanite, pyrite, zircon, sphene, apatite	
Pyroxene Gneiss	Granoblastic, equigranular	Weak	Weak	Quartz, pyroxene, microcline, plagioclase	Hornblende, chlorite	Apatite, magnetite, sphene	

Biotite Gneiss: Mapped along the west side of the Greenwood Project area, this rock type becomes graphitic to the north. It could be correlative with the graphite-biotite gneiss along the east flank.

Marble: Marble has only been found in drill core. In hole G-7 it is intercallated with pyroxene-rich rock, and in hole W-2 it occurs as a zone of porous, coarse-grained calcite in a fault zone.

Pyroxene-rich Rock ("Pyroxenic gneiss" in Offield, 1967): This unit occurs as a discontinuous horizon along the east flank of Warwick and Taylor Mountains as pods or layers of 30 to 95% diopside. In some locations it grades into pyroxene gneiss, elsewhere it is interbedded with marble, graphitic-biotite gneiss, or pegmatite. In drill hole W-1 the pyroxene-rich rock contains large clots of garnet and particularly abundant interstial pyrite, chalcopyrite, and pyrrhotite (up to 15% locally).

Microcline Gneiss ("Quartz-microcline-plagioclase gneiss" in Offield, 1967): This is the most abundant rock type in the map area and is the predominant unit along the crest of Warwick and Taylor Mountains north of the microwave tower (Figure 3).

Hornblende Gneiss ("Hornblende-feldspar gneiss" in Offield, 1967): Hornblende gneiss is the predominant unit south of the microcline gneiss. These two units appear to grade into each other in the vicinity of the microwave tower.

Pyroxene Gneiss: This rock type contains 5 to 25% pyroxene and often occurs in association with the zones of pyroxene-rich rock. The only large area of outcrop is in the south-central portion of the Greenwood Project; here, this unit is not associated with pyroxene-rich rock.

The rocks grouped between the pyroxene gneiss and the graphite-biotite gneiss on Table 1 are interpreted as a sequence of interbedded sediments and volcanics. This interpretation is supported by the composition of these units (see discussion by Offield, 1967) and their outcrop pattern (Figure 4). The banded distribution of rock types on the east flank of Warwick and Taylor Mountains suggests bedded strata and the transition from microcline to hornblende gneiss can be interpreted as a facies transition in progenitor sediments.

The Grenville prograde metamorphism produced an upper amphibolite to lower granulite facies mineral assemblage in these rocks. Anatexis during this event generated the unzoned, podiformal pegmatites which are common at the Greenwood Project. The pegmatites exposed at the Warwick Project as continuous layers may be the product of metamorphism of rhyolitic ash falls (Kearns, 1977). Elsewhere in the Reading Prong anatexis produced other intrusives such as the Storm King Granite of eastern Orange County, New York (Helenek, 1971). Between the peak of prograde metamorphism at approximately 1100 m.y. and 925 m.y., these rocks were exposed to at least one stage of hydrothermal alteration and were intruded by uraniferous S-type granites and pegmatites. The diabase dikes intruded late in Precambrian time.

Offield (1967) proposes a major unconformity within the pyroxene gneiss to graphite-biotite gneiss sequence. He suggests that these rocks were the product of two separate periods of sedimentation and metamorphism. No conclusive evidence regarding this proposition was found in the course of our field work. It is clear, however, that the Grenville Orogeny was not one single event but a series of events spanning at least 150 million years between 1100 m.y. and 950 m.y.

Alteration

Alteration of the prograde mineral assemblages is expressed by: epidotization, epidote veining, pink staining of feldspar, and hematite staining associated with silica flooding. These features may be the product of a single hydrothermal event but are more likely the result of several events between 1100 m.y. and 950 m.y.

Epidotization consists of replacement and/or alteration of feldspar crystals by epidote. It is concordant with foliation and compositional banding. Epidote veining is a discordant feature in which epidote has filled cross-cutting fractures. The Greenwood and Warwick Projects are the only locations found in the Reading Prong in which either type of epidote is common. At these projects epidote is associated with surface radiometric anomalies and uraninite mineralization in core. The concordant epidotization shows the strongest correlation with uranium mineralization. Concordant epidotization is best developed at the Greenwood Project along the low ridge south of the Centennial Mine which parallels the magnetite mineralization on its east side. At the Warwick Project it is best displayed at New York state plane coordinates N442,450 and E493,750 along the north side of the small stream valley draining the west side of Taylor Mountain. Vein epidote occurs near most fault zones and is well displayed at Greenwood at New York state plane coordinates N436,050 and E491,350.

Pink staining of feldspars, most commonly microcline, is the result of extremely fine grained hematite disseminated through the feldspar crystals. It is not clear if the hematite was introduced by the alteration fluid or if the fluid oxidized pre-existing iron associated with the feldspars. The pink staining is often found with both types of epidote mineralization at Greenwood and it may form a halo around zones of concordant epidotization. It is also commonly found in the microcline and hornblende gneiss, away from epidotization, associated with weak radiometric anomalies. Pink staining is best displayed in drill holes G-4 and W-3. In these holes the pink staining forms alternating color bands which have sharp contacts and range in width from a few inches to several feet within a single rock type.

The final type of alteration, hematite staining associated with silica flooding, is independent of the first two types and is probably younger. The color of these altered rocks is a brick red to reddish brown, much darker that the pink staining. Often, limonite yellows, oranges, and browns are associated with the hematite. The silica flooding becomes apparent when efforts are made to break these rocks - they are very hard. This type alteration is usually anomalously radioactive, often extremely so. Several sites with greater than 20,000 cps (Mt. Sopris Scintillometer) have been located in the two known areas of this type alteration (Figure 4). These areas are associated with fractured rock near fault zones.

Structures

Dallmeyer (1972) has resolved three sets of folds in the Tuxedo Lake area, seven miles east of the Greenwood and Warwick Projects. He attributes all of these to the Grenville Orogeny, but they are probably the result of separate orogenic pulses within the period he labels "Grenville". Offield (1967) identified two large, north-plunging folds nearer the project area: the Sterling Forest syncline, five miles east of the project area and a well expressed anticline one mile west of the project area. Within our map area at Greenwood and Warwick, however, there is no evidence of folding at any scale. In his cross-section Offield represents this trend as an anticlinorium; we have no concrete data which either supports or refutes this interpretation.

Offield divides the Precambrian rocks which he mapped into east, middle and west blocks. These blocks are bound by major longitudinal faults along which major vertical displacement has juxtaposed rocks with different structural and metamorphic characteristics. The Greenwood and Warwick Projects are in Offield's middle block. The longitudinal fault forming the east boundary of the middle block truncates the Warwick - Taylor Mountain trend at the southeast end of the Greenwood Project. Movement on this fault created the chlorite schist described earlier.

Within the project area there are several smaller longitudinal faults which trend more westerly than the major longitudinal boundary fault. These smaller structures are approximately parallel to foliation, compositional banding, and rock contacts (Figure 4). Cutting the lithologic trends at high angles are several transverse faults and, at the Greenwood Project, numerous airphoto lineaments. The lineaments are formed by the alinement of outcrop escarpements and probably represent zones of fracturing which have been emphasized by glacial plucking. The concentration of these lineaments at the Greenwood Project suggests that that this area was more heavily fractured than the Warwick Project area to the north. A major change in both topography and U.S. Geological Survey aeromagnetic data (Henderson et al, 1957) occurs at the state line. This suggests significant offset along the proposed transverse fault at the south end of Taylor Mountain (Figure 4).

Magnetite Mineralization

There are four areas of magnetite mineralization in the Greenwood and Warwick Project areas which were mined in the 1700 and 1800's (Bayley, 1910, Colony, 1921, and Offield, 1967). These mines include: the Centennial Mine on the Greenwood Project, the Raynor Mine on the northwest flank of Taylor Mountain, and the Standish and Parrott Mines on Warwick Mountain (Figure 3). The Raynor workings are the most extensive, but even these are quite small compared to the larger mines of the Ringwood and Dover districts in New Jersey.

The magnetite ore bodies in the project area consist of massive zones of medium to coarse grained, rounded magnetite crystals. Interstial pyrite, chalcopyrite, and pyrrhotite ranges from 0.5 to 10% and silicate gangue minerals range from

1 to 30%. A 20 foot intercept of 90% magnetite was encountered in drill hole W-2. These massive intercepts are envisioned as high grade pods or layers within the zones of magnetite enrichment described earlier (Figure 2). Uraninite occurs with pyroxene, hornblende, and epidote crystals in the gangue or host rocks of the magnetite mineralization.

Uranium Mineralization

The uranium mineralization at Greenwood and Warwick is best categorized by the geometric terms stratabound and fracture-related. Categorizing this mineralization in the regional scheme of uranium shows previously discussed for the Reading Prong does not work as well. Here both magnetite-associated and granite-associated mineralization is present, and both types have been modified by hydrothermal alteration.

Stratabound uranium mineralization consists of zones 20 to 100 feet wide of 100 to 500 ppm uranium which contain bands 1 to 3 inches wide of 0.5 to 4% U_3O_8. The strike length of this type mineralization along the Centennial Mine trend at Greenwood is approximately 2400 feet. This type mineralization has also been identified on the Mania property at Warwick, but its strike length there has not been determined. The high grade mineralization consists of rounded, anhedral grains of uraninite 0.1 to 5 mm in diameter. These are disseminated along grain boundaries or within medium-grained crystals of diopside, hornblende, allanite, and epidote. Allanite is a particularly common host and is somewhat unusual in that microprobe analyses show that it contains no uranium, only rare-earth elements, mainly cerium and lanthanum. It appears that during crystallization all the uranium in the system was allocated to the uraninite. The mafic minerals hosting the high-grade intercepts occur as melanocratic bands 1 to 3 inches thick within luecocratic hornblende or pyroxene gneiss. The feldspars in the hosting gneiss are completely epidotized and magnetite, pyrite, and minor chalcopyrite are disseminated throughout the ore zone and hosting gneiss. Clots of coarse-grained diopside and layers of massive magnetite may also be associated with the uraninite horizons. Cataclastic textures have been identified in the stratabound horizons. These textures show evidence of open space which has been filled by epidote, allanite and uraninite. Stratabound mineralization is best displayed in the ore holes G-3 and W-3. It was also drilled in holes G-1, G-2, G-4, G-5, G-6, G-8 and W-1.

Fracture controlled mineralization refers to the uranium associated with the hematite-staining-silica-flooding alteration which is hosted in zones of broken rock. This uranium may have been remobilized from a zone of stratabound mineralization or introduced from a separate source, such as the late-stage anomalous granites. The uranium-bearing mineral has not been identified. Two areas with outcrops of this mineralization are shown on Figure 4. They occur on Warwick Mountain and the south flank of Taylor Mountain as generally concordant zones 10 to 300 feet wide and 1000 to 3500 feet long. There are intensely altered outcrops in these zones which yield samples assaying 0.05 to 2.5% U_3O_8. Neither of these zones has been tested by drilling.

As previously mentioned, mineralization was also found in an anomalous granite intercepted in drill hole G-7. The ten foot granite intercept produced a grade calculation of 0.08% eU_3O_8 from the gamma log. This is a luecocratic granite with white feldspars which intrude a marble. The radioactive mineral was not identified. The proximity of this granite to the major zone of fracture controlled mineralization on the south flank of Taylor Mountain (Figure 4) suggests that they may be genetically related.

EVALUATION OF THE GREENWOOD AND WARWICK PROJECTS

Appendix 2 contains a chronological synopsis of the work conducted between 1976 and 1980 by Exxon personnel at Greenwood, Warwick, and the Reading Prong. Our evaluation included geologic mapping, rock chip geochemistry and petrography, soil chemistry, ground geophysics, aeroradiometrics, and core drilling. The results of these efforts are summarized below.

Surface Data Collection

Geologic mapping, geochemical samples, and geophysical data were compiled on a topographic base map at a scale of 1:2,400. The base map was prepared from air photos by a New Jersey contractor; the New York state plane coordinate system was used for reference in both project areas. For additional control in this heavily forested terrain, a rectangular grid was surveyed over the property with stations every 100 feet along northeast-southwest lines which were spaced approximately every 400 feet in a northwest-southeast direction. Copies of the base map and grid with field geologic, geochemical, and geophysical data are filed with the Greenwood-Warwick materials.

Rock chip geochemistry and petrography was used to characterize the rock types and mineralization. In addition, petrography was often required to distinguish among the hornblende, pyroxene, and microcline gneisses. The geochem data and thin sections are also on file with the Greenwood-Warwick materials.

The soil samples collected over the grid were analyzed for U and Pb^{210}. The resulting anomalies were approximately coincident for both assays. From north to south the major anomalous areas include: 1) The summit of Warwick Mountain within the Mania and Giogrande properties; 2) the west slope of Taylor Mountain due north of the microwave tower within the Brady property; 3) the south flank of Taylor Mountain along the state line within the Wright and Sisters of Mercy property; 4) the Centennial Mine trend within the Weber property; and 5) the west side of the drainage in which G-7 and G-8 were drilled within the Mitchell property. The soil chemistry and surface radiometric data indicate that the anomalies over the microcline gneiss are due, in part, to the higher background uranium content of this rock type.

A Geometrics Unimag Magnetometer and a Geonics EM-16 were used to collect magnetic and very low frequency (VLF) data along the grid at 100 foot spacings and closer where warranted. The magnetics helped define the extent of the known magnetite deposits but did not detect hidden magnetite bodies. The VLF data helped confirm the extent of fracturing and faulting previously identified on air photos and on the ground. These data show the more uniformly fractured nature of the Greenwood block versus the Warwick block where fracturing is confined to restricted areas.

Surface radiometrics were collected on the grid and in the course of geologic mapping. These data identified anomalous outcrops which, for the most part, were within the soil sample anomalies. All anomalous outcrops are plotted on the field maps of Bailey, Carden, and Williams.

Drilling

Drilling at Greenwood and Warwick was conducted in four phases from late 1977 to early 1980. The hole locations are plotted on Figure 4. Table 2 summarized the objectives and results of these drill holes. The drilling was concentrated in three areas: the Centennial Mine trend at Greenwood, the Mania and Giogrande property at Warwick, and the fault zone east of the Centennial Mine on the Mitchell property at Greenwood.

One ore hole, one strong mineral, four weak mineral, and one anomalous hole were drilled in the Centennial Mine trend. These holes included G-1, G-2, G-3, G-4, G-5, G-6, and G-8. The first three holes were placed to evaluate the surface expression of magnetite and uranium mineralization. With the interception of ore grade uranium mineralization in G-3, holes G-4, G-5, and G-6 were drilled to test the north and south extension of this trend, and G-8 was drilled to test the extension of this trend at depth. The results indicate that, although high grade uranium mineralization is present, the probability of finding an Exxon-size ore body along this trend is low.

Hole G-7 tested the fault zone east of the Centennial Mine trend as well as the soil and surface radiometric anomalies east and west of the fault. The strong mineralization encountered in this hole was associated with an anomalous granite. As previously discussed, this intrusive could represent an additional source of uranium to this system or a mechanism for upgrading the Centennial stratabound mineralization. A drill hole was planned on the Sisters of Mercy property for the fall of 1980 to evaluate both the fault zone and the hematite-staining-silica-flooding alteration zone which parallels the fault zone north of G-7. This hole was cancelled, however, when the publicity problems erupted. This area is highly favorable for fracture-controlled mineralization; the planned hole, plus possible additional drilling, is needed to evaluate the alteration zone and fault.

Holes W-1, W-2, and W-3 (weak, strong, and ore respectively) were placed to evaluate various targets on the Mania and Grande properties of the Warwick Project. Stratabound uranium mineralization was intercepted in drill hole G-1 and G-3. Additional drilling is required to evaluate this mineralization. The negative evaluation of the Centennial stratabound mineralization at Greenwood should not be used in a guilt-by-association manner to condemn other stratabound mineralization in this area. The fracture-controlled mineralization intercepted in W-2 was also encouraging. Additional drilling in the fall of 1980 was planned to evaluate the zone of hematite-staining-silica-flooding alteration associated with the W-2 fault zone (Figure 4). This drilling is needed to complete an evaluation of this area.

A drill hole on the north end of the Brady property of the Warwick Project was also planned for the fall of 1980. This hole would have tested soil anomalies and surface uranium mineralization associated with epidotization in microcline gneiss. This drilling and possibly additional drilling further north along this trend is required to complete an evaluation of the Warwick Project area.

TABLE 2: DRILLING SUMMARY

Greenwood (U-4749) & Warwick (U-4878)

Passaic County, New Jersey & Orange County, New York

Hole[1] No	Classification	Total Depth	Data Completed	Dip	Bearing	Property Owner	Rock Types Intercepted[2]	Best Gamma Log Intercept	Objective	Results
G-1	Weak Mineral	353'	Dec 1977	50	S55 W	Weber	Hnbld gn, pyx gn, minor pyx-rich rock, minor magnetite concentrations	@206'-6'-0.046(0.073)	Test central portion of surface mineralization along Centennial Trend	Mineralization in pyroxene-rich rocks associated with magnetite & sulfides
G-2	Strong Mineral	673'	Oct 1978	60	N60 W	Weber	Hnbld gn, pyx gn, massive magnetite concentrations	@194'-6'-0.087(0.144)	Test southern end of surface mineralization along Centennial Trend	Mineralization in pyroxene-rich zones associated with massive magnetite
G-3	Ore	1445'	Nov 1978[3] May 1979	55	S70 E	Weber	Hnbld gn, pyx gn, minor pyx-rich rock, minor mag concentrations, chlorite schist	@521'-6'-0.210(0.540) @484'-50'-0.053(0.540)	Test northern end of surface mineralization along Centennial Trend	Ore-grade mineralization in pyroxene-rich zones within broad zones of low grade mineralization in hornblende & pyroxene gneisses
G-4	Weak Mineral	883'	June 1979	50	N70 W	Mitchell & Riggio	Hnbld gn, pyx gn, minor pyx-rich rock, minor mag concentrations, chlorite schist	@254'-6'-0.049(0.157) @241'-12'-0.034(0.072)	Test northern extension of Centennial Trend and fault zone to west	Penetrated upper portion of mineralized zone; no mineral in fault zone
G-5	Weak Mineral	854'	July 1979	50	S70 E	Riggio	Hnbld gn, minor pyx gn, amphibolite, docite	@430'-6'0.030(0.101)	Test northern extension of Centennial Trend	Minor mineralization; higher grade mineralization of G-1 to 4 pinches out or plunges deeper

TABLE 2: Continued

G-6	**Anomalous**	850'	Nov 1979	50	S30 E	Weber	Hnbld gn, pyx gn, minor pyx-rich rock, minor mag concentrations, chlorite schist	@613.0'-6'-0.011(0.032)	Test southern extension of Centennial Trend	Minor mineralization; south end of trend terminated by fault zone
G-7	**Strong Mineral**	1344'	Dec 1979	50	S60 E	Mitchel	Pyx-rich rock, graphitic-bio gn, marble, granite, hnbld gn, pyx gn, mic gn, chlorite schist	@530.0'-10'-0.080(0.141)	Test soil and radiometric anomalies associated with fault zone east of Centennial Trend	Strong mineralization in fault zone associated with granite; weak mineralization in microcline gneiss
G-8	**Weak Mineral**	1492'	Jan 1980	50	N65 E	Mitchel	Graphitic-bio gn, pyx-rich rx, hnbld gn, minor mag conc, pyx gn	@774'-6'-0.031(0.126)	Test Centennial Trend at depth	Minor mineralization; no extension of G-3 mineralization at depth
W-1	**Weak Mineral**	1045'	Oct 1979	50	N30 W	Mania	Pyx-rich rock, minor mag conc, mic gn	@572.5'-6'-0.047(0.154)	Test northern portion of U-bearing magnetite trend & possible fracture zone	Mineralization in pyroxene-rich rock; minor mineralization in microcline gneiss
W-2	**Strong Mineral**	1002'	Nov 1979	50	N39 E	Giogrande Mania	Mic gn, marble	@295.0'-6'-0.151(0.145)	Test fault zone and associated soil anomalies	Mineralization in fault zone; minor mineralization in microcline gneiss
W-3	**Ore**	968'	Dec 1979	50	N50 W	Mania	Mic gn, pyx-rich rx, minor mag conc	@34.0'-6'-0.103(0.330)	Test subsurface extent of surface shows and major soil anomalies	Ore-grade mineralization in pyroxene-rich rock; minor mineralization in microcline gneiss

[1] **G - designates drill hole at Greenwood**
W - designates drill hole at Warwick

[2] Rock Type Abbreviations:

bio - biotite	mag - magnetite
conc - concentrations	mic - microcline
gn - gneiss	pyx - pyroxene
hnbld - hornblende	rx - rock

[3] Hole G-3 drilled to 813 feet in 1978; deepened to 1445 feet in 1979.

Conclusions

Of the eleven holes drilled on the Greenwood and Warwick Projects, two were ore holes, three were strongly mineralized, five were weakly mineralized, and one was anomalous. These are very favorable results, particularly for a target in a frontier area. Clearly, the Greenwood and Warwick Project areas are a uranium-enriched district. Uranium mineralization is found in stratabound settings, in zones of fracture-controlled hydrothermal alteration, and in an anomalous granitic intrusive. All three types could conceivably host an Exxon-size ore body.

Drilling has eliminated the Centennial Mine trend as having potential for hosting an Exxon-size ore body. Four areas remain, however, which require drilling to complete an evaluation of these projects. Listed by priority, these include:

1) The alteration and fault zone along the east side of the Greenwood Project.

2) The alteration and fault zone of the Mania and Grande properties, Warwick Project.

3) The uranium-bearing zone of epidotization in microcline gneiss at the north end of the Brady property, Warwick Project.

4) The stratabound uranium mineralization of the Mania property, Warwick Project.

READING PRONG RECONNAISSANCE

Most of the known uranium shows in the Reading Prong were visited, sampled, and evaluated in a cursory manner. This information has been filed with the Greenwood and Warwick materials. Those areas meriting further work on the basis of favorable geology are described and priorized in Table 3. When compared with these other shows, the Greenwood and Warwick Project area is the most favorable for hosting a large ore body. Additional work at these other sites, however, might upgrade their ranking by identifying zones of fracturing and hydrothermal alteration.

TABLE 3: URANIUM SHOWS OF THE READING PRONG MERITING FURTHER EVALUATION

Name	Location	Land Check/ Submittal #	Type of Show
Highly Favorable			
Cranberry Lake	South shore Cranberry Lake Sussex County, N.J.	U-5635 U-5833	Magnetite associated
Woodstock	Bowling Green Mountain, 2 miles NW of Tierney's Corner, Passaic County, N.J.	U-5653	Anomalous granite
Camp Smith	Camp Smith Military Reservation Peekskill, Westchester, N.Y.		Magnetite associated
Favorable			
Andover Mine	2 miles NW of Andover Sussex County, N.J.		Magnetite associated
Jenny Jump Belt	Jenny Jump Mountain & Washington Mine between Washington & Hope Warren County, N.J.		Magnetite associated, marble associated, anomalous granite and undefined road shows
Potential			
Ringwood	Ringwood Mine, Ringwood Passaic County, N.J.	U-5636	Magnetite associated
Maple Hill	One mile west of Greenwood Project Passaic County, N.J.	U-5637	Anomalous granite
Hacklebarney Belt	Between Clinton & Chester Hunterdon & Morris Counties, N.J.		Undefined road shows and magnetite associated
Splitrock Belt	Between Dover & Butler Passaic County, N.J.		Magnetite associated and undefined road shows

READING PRONG METALLOGENIC MODEL

The results of our investigations in the Reading Prong support a model for metallogenesis involving syngenetic deposition of metals in a sedimentary/volcanic setting, recrystallization and possible concentration during Grenville prograde metamorphism, and upgrading during late-Grenville intrusion and alteration. This syngenetic-metamorphic model is favored by three lines of evidence: 1) The stratabound nature of all iron and zinc mineralization in the Prong as well as much of the uranium and rare-earth element mineralization; 2) The interpretation of the host rocks as metamorphosed sediments and volcanics; and 3) Recent geochemical work on several iron and zinc deposits by Fondel and Baum (1974), Kearns (1977), Cooper (1978), and Kastelic (1979). The following discussion elaborates on details and applications of this model.

Deposition and Initial Concentration

Deposition of the rocks which comprise the Reading Prong occurred in pre-Grenville time, probably between 1400 and 1200 m.y. ago. Erosion of the Canadian Shield provided a source of continental clastics from the west which were interbedded with carbonate sediments in a near-shore to shelfal environment. Local evaporite conditions dolomitized some of the carbonate sediments by evaporative-reflux (Blatt et al, 1972) and produced limited horizons of evaporite minerals. Intermediate to siliceous composition volcanoclastics were added to these sediments from the east by distant volcanism. This sedimentary volcanic environment suggests a tectonic setting similar to modern back-arc basins.

Iron and zinc were most likely introduced to this environment by a Red-Sea-type brine system as suggested by Kearns (1977) and Cooper (1978). Plumbing, a heat source, and a metal source for the brine system were possibly provided by back-arc rifting associated with the intrusion of mafic igneous rocks at depth. The sulfide mineralization seen at Camp Smith, New York and in lesser concentrations in northern New Jersey could have also been introduced by the brine system. An alternative hypothesis suggested by Grauch, 1978 (after models by Hutchinson, 1973; Ridler, 1973; and Parak, 1975) is that the sulfides represent distal massive sulfide mineralization associated with submarine volcanism. In this interpretation the magnetite is an iron-oxide facies associated with the volcanism which overlaps and extends beyond the massive sulfide facies. This model, however, lacks a neat explanation of the zinc-oxide mineralization at Franklin.

Uranium was probably introduced to this environment by erosion of continental materials and/or by alteration of siliceous volcanoclastics. During pre-Grenville time, the near shore to shelfal environment would have been the primary setting where uranium, sourced by these mechanisms, could be trapped. Three processes in this environment could have precipitated uranium: 1) Reduction by decomposition of algal mats; 2) Concentration by evaporative processes as suggested by Schrader and Furbish (1976) and as seen at the

Yeliree calcrete deposit in Australia; and 3) Scavaging of uranium from sea water by hot metalliferous brines and sediments as suggested by Ku (1969). Uranium concentrated by these mechanisms could have been upgraded by multiple cycles of dissolution by hydrothermal fluids passing through the hosting sediments and reprecipitation by the same mechanism active elsewhere in the section.

The regional zonation of metal deposits in the Reading Prong described early is explained by this geologic model. Camp Smith, the occurrence with the greatest volcanic component, is on the east side of the Prong closest to the proposed volcanism. The carbonate-hosted Franklin deposit is on the west side of the Prong, farthest from the volcanism. Greenwood and Warwick, which contain components of both extremes, are spatially intermediate to the two.

Grenville Prograde Metamorphism

The peak of Grenville prograde metamorphism occurred at approximately 1100 m.y. Maximum temperatures ranged from 600 to 860°C and maximum pressures of 6 to 8 kilobars (Dallmeyer, 1974; Kearns, 1977; Carvalho & Sclar, 1979). These metamorphic conditions, upper amphibolite to granulite facies, produced the prograde mineral assemblages and textures in the paragneisses and marbles. The pyroxene-rich rock was produced by metamorphism of dolomite horizons. Scapolite gneisses were produced by metamorphism of evaporite horizons. Local anatexis produced the unzoned, podiformal pegmatites. The pegmatites cropping out as continuous horizons were probably produced by metamorphism of siliceous volcanoclastic horizons. Plastic deformation and intrusion of granitic plutons also accompanied this metamorphism.

The iron and zinc concentrations were generally recrystallized in place to form the magnetite-hematite and franklinite-willemite-zincite deposits. The only significant reconcentration of these metals occurred during plastic deformation when some of these horizons flowed short distances into low pressure zones along fold noses to form cylindrical ore bodies. Similarly, some of the uranium was metamorphosed in situ with little or no movement to form the stratabound mineralization seen at Greenwood and Warwick. Other uranium may have been mobilized by metamorhpic and/or anatextic fluids and redeposited in physical traps, like low pressure zones in fold noses, or chemical traps, such as magnetite, sulfide, and mafic mineral horizons (Welin, 1961, and Belevtsev, 1980).

Late-Grenville Alteration and Intrusion

Following the peak of prograde metamorphism, the alteration assemblages at Greenwood and Warwick were developed and the anomalous, S-type granites were intruded. The timing of these events is not clear. R. I. Grauch of the U.S. Geological Survey has been conducting an age dating program in the northern Reading Prong. All of his U-Pb dates on uraninite collected at Camp Smith, New York; Ringwood, New Jersey; and Greenwood cluster around 950 m.y. (Personal

Communication, 1980). This suggests a significant thermal event at that time which set uraninite ages throughout the northern Prong. It is plausible that the intrusion of the anomalous granite and the development of all the alteration assemblages occurred at 950 m.y., or that these events occurred earlier and the ages were reset by a final thermal peak at 950 m.y. Additional uraninite dating and work on the paragenesis is required. Despite the uncertainties, it is clear that the syngenetic mineralization was modified by at least one hydrothermal event. This modification was associated, at least in part, with brittle deformation which could provide the open space needed for the development of high grade uranium mineralization. After the setting of the uraninite dates at 950 m.y., there appears to be no event having significant impact on the uranium mineralization. Hence, the major effect of the Taconic, Acadian, and Appalachian orogenies in the northern Reading Prong was reactivation of brittle structures and uplift.

Analogs and Applications of the Model

There are no well-known, straight-forward analogs for the uranium mineralization in the Reading Prong. In the Proterozoic rocks of the Ukraine in the Soviet Union there is uranium mineralization associated with magnetite deposits hosted in upper amphibolite to lower granulite facies metamorphic rocks (Smirnov, 1977; Elevatorski, 1979; and Belevtsev, 1980). The descriptions of these deposits are sketchy, but they appear to be similar to the Reading Prong mineralization. R. I. Grauch (Personal Communication, 1978) has suggested that the Michelin and Kitts Deposits of Labrador, Canada (Gandhi, 1978) and the Kopparasen deposit of Norrbotten County, Sweden (Adamek, 1975) may be similar deposits of lower metamorphic grade. The Mary Kathleen deposit of Queensland, Australia (Derrick, 1977, and Cruikshank et al, 1979) may also be similar. The host rocks at Mary Kathleen are metasediments, and the Burstall Granite may be analogous to the late-stage, anomalous granite of the Reading Prong. In addition, allanite is commonly associated with uraninite at both Mary Kathleen and the Greenwood Project.

These possible analogs suggest the merit of applying this model to other terranes. In the United States the best, immediate application is to other Grenville rocks of the Appalachian system. Our competitors have investigated two other uranium occurrences in the Appalachians which are probable applications of this model: the North Harper Creek mineralization of the Grandfather Mountain Window, North Carolina, investigated by Framco from 1975 to 1978; and the Ludlow, Vermont mineralization of the Green Mountain Anticlinorium, investigated by Urangesellchaft in 1978 and 1979.

For evaluating other prospects with this model there are three critical parameters which will determine the merit of the prospect:

1) The presence of a progenitor source of uranium - metasediments, particularly with graphitic and evaporite horizons.

2) The development of upper amphibolite to lower granulite facies metamorphism to mobilize and initially concentrate uranium (see discussion by Belevtsev, 1980).

3) Post-metamorphic, hydrothermal events associated with brittle deformation to provide final upgrading mechanisms and open space for hosting high grade mineralization.

COMPETITOR ACTIVITY

Chevron and Sohio were the most active companies in the Reading Prong, other than ourselves. Chevron acquired the lease for 40 acres adjoining the Mania property of the Warwick Project which includes the old Taylor (Parrott) Magnetite Mine. They drilled three holes in this block in early 1980 and probably encountered some weak mineralization. Nevertheless, later that year when the public relations furor arose, they dropped the block.

Sohio's efforts were further south on the anomalous granite target at Bowling Green Mountain, Passaic County, New Jersey. This area corresponds to our Woodstock land check (U-5653). After acquiring a land block, they conducted geologic mapping, geochemical sampling, and geophysical data collection. They had planned to drill the block in 1980, but their efforts started the public relations controversy which terminated all uranium exploration efforts in the Reading Prong.

Martin and Trost, Duval, and several utility groups also expressed interest in the Reading Prong. To our knowledge, Martin and Trost was the only company to acquire land, the 23 acre Giogrande block which adjoins the Mania property of the Warwick Project. In 1979 they sold us the lease for that property and terminated their activity.

PUBLIC AFFAIRS - LESSONS LEARNED

Hopefully, the abandonment of the Greenwood and Warwick Projects will be a painful lesson in public affairs for our company. The important lesson to be learned from this experience is that a public affairs strategy must be incorporated in plans for evaluating prospects in areas with high population density. When the public controversy arose over our activity, we were caught unprepared. In the future, we should be ready with a layman's version of the technical information needed to back our position on all nuclear-related issues. In addition, we should have a plan established for disseminating this information to the appropriate individuals.

A second lesson derived from the Greenwood-Warwick experience is that the geologic evaluation of other projects in sensitive areas must be executed as rapidly as possible. A project evaluation plan with provisions for contingencies should be prepared in advance so that once begun, project evaluation does not stop until completion. The objective should be to complete the evaluation before public reaction develops.

Specific suggestions for a public affairs strategy have been made in a memo dated February 3, 1980, from this author to M. N. Slater with regard to the Thorpe Project (U-3542), Carbon County, Pennsylvania.

CONCLUSIONS

Evaluation of the Greenwood and Warwick Projects was not completed because of unfavorable public reaction to uranium exploration. These project areas have high potential for hosting a high-grade uranium deposit. Should the political climate change such that we could resume evaluating this area, drilling should be planned on the following targets listed by priority:

1) The hematite-stained-silica-flooded zone of hydrothermal alteration along the state line. The first drill hole should be located on the Sisters of Mercy property, Greenwood Project. It should be spudded west of the alteration zone and drilled east at a 45 to 50° vertical angle until the fault zone east of the alteration is intercepted.

2) The hematite-stained-silica-flooded zone on the Mania property, Warwick Project. The first hole should be spudded on the north side of the Mania access road, east of the alteration zone, and drilled west through the alteration zone at a vertical angle of 45 to 50°.

3) The epidote alteration zone due north of the microwave tower on the Brady property, Warwick Project. Additional ground work will be required to select the optimum drill site for this target.

4) The stratabound mineralized zone along the west side of the pyroxene-rich rock unit on the Mania property, Warwick Project. The first drill hole on this target should be spudded approximately 500 feet north-northeast of the Mania home. It should be drilled west-northwest through the magnetite zone well into the microcline gneiss which lies west of the pyroxene-rich rock.

Should reconnaissance work in the Reading Prong become favorable, Cranberry Lake, Woodstock, and Camp Smith should receive the highest priority. Other areas, suggested in the "Reading Prong Reconnaissance" section of this report, should also be evaluated.

A syngenetic-metamorphic model for metallogenesis in the Reading Prong was developed. This model can make an on-going contribution to our Frontier uranium program through its application in other areas. It should be particularly valuable in evaluating other uranium occurrences in Grenville rocks of the Appalachian system.

Two important lessons in public affairs should be garnered from this work. First, a public affairs strategy must be incorporated in plans to evaluate any uranium prospect in areas with high population density. Secondly, geologic evaluation, particularly drilling, should be planned for rapid execution so that the company will know the geologic merits of defending a property should it be required.

APPENDIX 1: STORAGE OF GREENWOOD, WARWICK, AND READING PRONG MATERIALS

The materials collected during the evaluation of Greenwood, Warwick, and the Reading Prong have been stored in four locations in Denver. Data, operational records, thin sections, and computer data have been stored in four boxes which are in the Central Files of U.S. Exploration, Exxon Minerals Company. A selection of maps and air photos are stored in three rolls in the Dead Map File of the Frontier Uranium Group. Representative samples of the core from each drill hole are stored in the Skeletonized Core Library of U.S. Exploration. The remaining core and rock chip samples have been donated to the U.S. Geological Survey and are stored in their Core Library in Golden. R. I. Grauch of the Branch of Uranium and Thorium will incorporate this data into his regional studies of the Reading Prong.

Lists of the specific materials filed in Central Files and the Frontier Dead Map File follow.

Central Files

Box 1 - Data & Operation Records

- Aerial Photos
- Aeromagnetic Data
- Aeroradiometric Data
- Age Dates
- Amphibolite Geochemistry
- Base Map and Grid
- Completion Report
- Data Comparison
- Drilling Data: G-1, 2 and 3
- Drilling Data: G-4 and 5
- Drilling Data: G-6, 7 and 8
- Drilling Data: W-1, 2 and 3
- Drilling Records 1980
- Drilling Records 1979
- Drilling Records 1977
- Field Note Books
- Financial Records 1980
- Financial Records 1979
- Financial Records 1978
- Geochem Data: Computer Format
- Geochem Data: Core Samples

Box 2 - Data & Operation Records

- Geochem Data: Master File
- Geochem Data: Rock Chip Samples
- Geochem Data: Soil Samples
- Geologic Maps and Reports
- Geophysical Data
- Land Checks: Reading Prong
- Land Records: Greenwood and Warwick
- Maps
- Metamorphic Model
- Microprobe Data
- Petrographic Data
- Permits
- Pyroxenite Data
- Public Relations
- Recon Data: Reading Prong
- Regulations
- Sample Locations
- Spectrometer and Magnetic Data 1977
- Size Potential
- Submittals: Reading Prong

Box 3 - Literature

- Literature Review Summaries
- Airborne Geophysics
- Base Metals - Reading Prong
- Beemerville Carbonatite Complex
- Courtland Complex
- Camp Smith Uranium Occurrence, NY
- Glacial Geology
- Geology, Local Areas, New Jersey
- Geology, Local Areas, New York
- Geology, Pennsylvania
- Geology, Regional Maps and Literature
- Magnetite Deposits
- Publication Lists
- Rare Earth Occurrences
- Uranium - Government Recon
- Uranium - Published Accounts

Box 4 - Petrographic Materials & Computer Data

Petrographic Materials *

Thin sections d.d.h. G-1
Thin sections d.d.h. G-3, -5, -7
Thin sections d.d.h. G-4
Thin sections Reading Prong Recon
Thin sections M. H. Bailey - Warwick Area
Thin sections M. H. Bailey - Warwick Area
Thin sections J. R. Carden - Greenwood Area
Thin sections R. Guzowski - Greenwood and Bowling Green Mountain
Microprobe-Sections d.d.h. G-2 and G-3
Microprobe-Sections J. R. Carden Samples
Oversized thin sections d.d.h. G-3, -4, -5 and Reading Prong Recon
Thin section chips M. H. Bailey Samples Box 1
Thin section chips M. H. Bailey Samples Box 2
Thin section chips M. H. Bailey Samples Box 3
Thin section chips R. Guzowski Samples
Thin section chips Reading Prong Recon Samples
Pyroxenite Study Samples

Computer Data

Computer tapes for Century Compi-log Logs of drill holes G-3, -4, -5, -6, -7, -8 and W-1, -2, -3
Computer tapes (2) with above data transcribed to IBM-compatible, 9 track format
Documentation for IBM-compatible format
Data cards (2 boxes) of geochem data collected at Greenwood and Warwick
Computer listing of above data cards

* Note: Thin section chips for core samples stored with core skeletons in Exxon core warehouse.

Dead Map File

Greenwood & Warwick Maps

Greenwood-Warwick Final Budget Map, Overlays and Topo Base
Warwick-Taylor Mountain Region-Offield Geology and Topo Base
Greenwood Geology-J. R. Carden, Mylar
Warwick Geology-M. H. Bailey, Mylar
Greenwood-Warwick 1"=200' Topo Base, Mylar Copy with Grid Lines
Greenwood-Warwick 1"=200' Topo Base, Paper Copy with Land Boundaries
Greenwood 1"=200' Topo Base, Mylar Copy of Surveyors Original
Warwick 1"=200' Topo Base, Mylar Copy of Surveyors Original
Greenwood 1"=200' Topo Base, Mylar Copy with Grid Lines
Warwick 1"=200' Topo Base, Mylar Copy with Grid Lines

Reading Prong Maps

Reading Prong Recon Map, Overlay and Mylar Original
D.O.E. Aeroradiometrics (GJBX-90(80)) at scale 1:62,500 with topo base showing known show locations
Reading Prong 1:125,000 Topographic Base with overlay showing outcrop of Precambrian rocks
Reading Prong 1:250,000 Topographic Base

Greenwood & Reading Prong Airphotos

Greenwood Photo Enlargements
Northwestern Reading Prong Photo Mosaic
Reading Prong Landsat Images

APPENDIX 2: CHRONOLOGY OF EXXON ACTIVITY IN THE READING PRONG

December 1976: Field check of submittal from J. Riggio by R. Pliler and S. P. Collings in West Milford Township, Passaic County, New Jersey.

Spring 1977: Follow-up recon in Warwick-Taylor Mountain area and general recon throughout Reading Prong by R. Pliler; aeroradiometric program flown over northwestern Reading Prong.

Summer 1977: Mapping, sampling, and geophysics in the Warwick-Taylor Mountain area by R. E. Williams as a summer geologist; initial land acquisition; R. Pliler leaves Exxon.

October-December 1977: Detail mapping of portion of Greenwood block and Bowling Green Mountain, Jefferson Township, New Jersey by R. Guzowski; drilling of G-1 (anomalous).

January 1978: S. P. Collings leaves Exxon.

Spring 1978: Soil sampling of portion of Greenwood block by G. P. Caves and W. C. Kennedy.

October-December 1978: Drilling of G-2 (strong mineral) and G-3 (ore) by R. E. Williams; renewed efforts at land acquisition.

Spring 1979: Soil sampling, ground geophysics (EM-16 and magnetics), and detail mapping of Greenwood and Warwick blocks by M. H. Bailey, H. G. Brown, G. P. Caves, J. R. Carden, W. C. Kennedy, and R. E. Williams; drilling of G-3 (weak mineral); reconnaissance of other shows in Reading Prong by R. E. Williams.

Fall 1979: Drilling of G-6 (anomalous), G-7 (strong mineral), G-8 (weak mineral), W-1 (weak mineral), W-2 (strong mineral), and W-3 (ore); inquiries from public, press, and town officials of Warwick, informal responses by R. E. Williams alleviates fears.

Spring 1980: Analysis of data amassed in 1979, detail core logging, development of metallogenic model, follow-up mapping and soil sampling, selection of drill sites for final evaluation.

Summer 1980: Press in New Jersey begins inaccurate coverage of Exxon's activities and those of Sohio in Jefferson Township, New Jersey; anti-nuclear groups begin lobbying for legislation to ban exploration.

Fall 1980: Bans on exploration and mining passed in Jefferson and West Milford Townships, New Jersey as well as Warwick Township, New York; Exxon cancels Greenwood and Warwick projects.

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